Description

# Driver circuit with frequency-dependent signal feedback

The invention relates to a driver circuit for driving a useful signal in accordance with the preamble of Patent Claim 1.

Figure 1 shows a driver circuit according to the prior art for driving a useful signal.

The driver circuit illustrated in Figure 1 is of differential construction and contains two operational amplifiers OPA, OPB for signal amplification. The operational amplifiers amplify a useful signal arriving from a signal source and output the amplified useful signal via protection impedances $Z_a$, $Z_b$ to a connected terminal, for example a telephone T. The operational amplifiers are integrated for example in an SLIC circuit situated on a line card. The operational amplifiers each have a low output impedance for the signal amplification of the useful signal. The impedances connected downstream of the two operational amplifiers serve to protect the amplifier circuits and for electromagnetic compatibility (EMC). The output impedances $Z_a$, $Z_b$ preferably protect the amplifier circuit from overvoltages, which may be caused by a flash of lightning, for example, and for the suppression of interference signals, for example radio signals.

Figures 2a to 2c show practical realizations of the protection impedances $Z_a$, $Z_b$ according to the prior art.

The driver circuit illustrated in Figure 1 is of differential construction, the components being symmetrical, i.e. in particular the two protection

impedances $Z_a$, $Z_b$ are as far as possible of identical construction in order to have a maximum longitudinal conversion loss. In communication systems, for example appertaining to voice telephony, the driver circuit for driving the useful signal must satisfy very stringent circuitry requirements with regard to the longitudinal conversion loss LCL. The standards relevant to the longitudinal conversion loss are the TR57 standard in the USA and the Q552 and G712 standards in Europe.

Figure 3 shows a measuring circuit for determining the longitudinal conversion loss LCL.

Figure 4 shows an associated equivalent circuit diagram. The output impedance $Z_{out}$ illustrated in the equivalent circuit diagram is the output impedance of the overall circuit to the left of the output pads Outa, Outb for the SLIC circuit in Figure 1. The measuring circuit illustrated in Figure 3 serves for measuring the longitudinal conversion loss LCL. A signal source feeds a sinusoidal measurement signal into the two output pads A, B of the line card via feed-in resistors $R_L$. The two measuring resistors $R_L$ are high-precision resistors with matching resistances. The voltage between the two output pads A, B is measured.

The following holds true for the longitudinal conversion loss:

$$\mathrm{LCL} = 20 \cdot \log\left|\frac{V_L}{V_T}\right| \qquad (1)$$

The following relationship holds true between the longitudinal conversion loss LCL and the impedances

illustrated in the equivalent circuit diagram according to Figure 4:

$$LCL = 20 \cdot \log \left| \frac{1}{\frac{Z_{out} + \Delta Z}{R_L + Z_{out} + \Delta Z} - \frac{Z_{out}}{R_L + Z_{out}}} \right| \qquad (2)$$

The high-precision feed-in resistors $R_L$ have a value of 300 ohms, for example. The impedance difference $\Delta Z$ between the output impedances exists because of manufacturing tolerances and inaccuracies of the protection impedances $Z_a$, $Z_b$ in the conventional driver circuit as illustrated in Figure 1.

With the applicable condition $\Delta Z \ll R_L$, equation (2) can be greatly simplified to:

$$LCL \cong 20 \cdot \log \left| \frac{R_L + Z_{out}}{\Delta Z} \right| \qquad (3)$$

To ensure that the longitudinal conversion loss is as high as possible and LCL thus assumes a maximum value, conventional driver circuits have hitherto used expensive output impedances with high accuracy, i.e. impedances which have very small tolerances during production. Such components which have to satisfy very high accuracy requirements can only be produced with considerable technical outlay and high costs.

Therefore, the object of the present invention is to provide a driver circuit which, with the use of components with relatively large manufacturing tolerances, nevertheless ensures a very high longitudinal conversion loss LCL.

This object is achieved according to the invention by means of a driver circuit having the features specified in Patent Claim 1.

The invention provides a driver circuit for driving a useful signal having
at least one amplifier circuit with low output impedance for the signal amplification of the useful signal,
a protection impedance respectively connected downstream of the amplifier circuit and serving to protect the amplifier circuit,
provision respectively being made of a feedback circuit for the frequency-dependent signal feedback of the useful signal amplified by the amplifier circuit.

The amplifier circuit is preferably an operational amplifier having an inverting signal input, a noninverting signal input and a signal output.

The protection impedance is preferably connected between the signal output of the operational amplifier and a signal line connection for the connection of a signal line.

The signal line is preferably a telephone line for connecting a telephone to the driver circuit.

The driver circuit is preferably of differential construction and has two symmetrically constructed amplifier circuits,
two symmetrical protection impedances and two symmetrically constructed signal feedback circuits being provided.

The signal feedback circuits preferably respectively contain a capacitor, which is connected between the signal output of the operational amplifier and a signal input of the operational amplifier, and also a resistor, which is connected between the signal line connection and a further signal input of the operational amplifier.

The signal feedback circuit feeds back high-frequency signal components of the useful signal amplified by the amplifier circuit to the signal input of the amplifier circuit to a greater extent than low-frequency signal components of the useful signal amplified by the amplifier circuit, so that the output impedance of the driver circuit is reduced in a specific first frequency range up to a first predetermined limiting frequency ($f_{G1}$) which lies above the second limiting frequency ($f_{G2}$) of the useful signal.

In this case, the first frequency range comprises a second frequency range preferably provided for the transmission of a useful signal.

The second frequency range is preferably the voice signal band for the transmission of a telephone voice signal.

In this case, the limiting frequency ($f_{g2}$) of the useful signal is preferably about 4 kHz.

Preferred embodiments of the driver circuit according to the invention are described below with reference to the accompanying drawings in order to elucidate features that are essential to the invention.

In the figures:

Figure 1 shows a driver circuit for driving a useful signal according to the prior art;

Figure 2 shows various embodiments of protection impedances for protecting the amplifier circuits according to the prior art;

Figure 3 shows a measuring circuit for measuring the longitudinal conversion loss of a driver circuit according to the prior art;

Figure 4 shows an equivalent circuit diagram for the measuring circuit illustrated in Figure 3;

Figure 5 shows a preferred embodiment of the driver circuit according to the invention for driving a useful signal;

Figure 5 [sic] shows a diagram illustrating the output impedance of the driver circuit according to the invention as a function of the frequency.

A preferred embodiment of the driver circuit according to the invention for driving a useful signal is explained in detail below with reference to Figure 5. The driver circuit 1 as illustrated in Figure 5 serves for driving a useful signal, for example a voice signal for the transmission of an analog voice signal to a telephone terminal.

Figure 5 shows a measuring circuit for measuring the longitudinal conversion loss LCL in the driver circuit 1 according to the invention. The driver circuit 1 illustrated in Figure 5, which is of differential construction, contains two signal inputs 2a, 2b for receiving a useful signal to be driven. The driver

circuit 1 furthermore contains two amplifier circuits 3a, 3b in the form of operational amplifiers each having a noninverting input 4a, 4b and an inverting signal input 5a, 5b. The noninverting signal input 4a, 4b is connected to the associated signal input 2a, 2b via a signal line 6a, 6b. The operational amplifier 3a, 3b respectively has a signal output 7a, 7b. The signal output 7a, 7b of the operational amplifier is connected via a line 8a, 8b to a protection impedance 9a, 9b connected downstream. The protection impedance 9a, 9b respectively serves to protect the amplifier circuit 3a, 3b. The protection impedances 9a, 9b are constructed for example as illustrated in Figures 2a to 2c. The protection impedances 9a, 9b are connected to the output pads 11a, 11b of the line card 12 via lines 10a, 10b.

In the measuring circuit for measuring the longitudinal conversion loss as illustrated in Figure 5, the output pads 11a, 11b of the line card 12 are connected to a feed-in signal source 13 via measuring resistors 12a, 12b. The signal source 13 is a voltage source which feeds a sinusoidal measurement signal into the output connections 11a, 11b of the line card 12 via the measuring resistors 12a, 12b.

The driver circuit 1 according to the invention as illustrated in Figure 5 additionally has electrically constructed feedback circuits 14a, 14b. The feedback circuits 14a, 14b carry out a frequency-dependent signal feedback of the useful signal amplified by the associated amplifier circuit 3a, 23b [sic] to a signal input of the amplifier circuit 3a, 3b. The signal feedback circuits 14a, 14b respectively contain a capacitor 15a, 15b, which is connected between the signal output 7a, 7b of the associated operational amplifier 3a, 3b and a signal input 5a, 5b of the operational amplifier. In the

embodiment illustrated in Figure 5, the useful signal is fed back to the inverting input 5a, 5b of the associated operational amplifier 3a, 3b. In addition, the signal feedback circuits 14a, 14b respectively contain a resistor 16a, 16b, which is connected between the signal line connection 11a, 11b and the inverting signal input 5a, 5b of the operational amplifier 3a, 3b. The signal feedback circuits 14a, 14b of the driver circuit 1 of differential construction each have two inputs 17a, 17b, 18a, 18b. The first input 17a, 17b of the signal feedback circuit 14 is connected to the connecting line 10 between the protection impedance 9 and the signal line connection or pad 11. The second signal input 18 of the signal feedback circuit 14a, 14b is connected to the connecting line 8 between the operational amplifier 3 and the protection impedance 9. The signal feedback circuits 14a, 14b respectively have a signal output 19a, 19b, which is connected to the inverting input 5a, 5b of the associated operational amplifier 3a, 3b via a feedback line 20a, 20b.

The signal feedback circuit 14a, 14b in each case carries out a frequency-dependent signal feedback of the useful signal to the inverting input 5a, 5b of the operational amplifier 3a, 3b. In this case, high-frequency signal components of the useful signal amplified by the amplifier circuit 3a, 3b are fed back to the inverting input 5a, 5b of the operational amplifier 3a, 3b to a greater extent than the low-frequency signal components of the amplified useful signal. As a result of this, the output impedance is reduced in a frequency range up to a limiting frequency $f_{g1}$. The protection impedances 9a, 9b are included in the feedback loop or control loop for low signal frequencies, in particular in a specific signal band, so that the output impedance of the driver circuit is greatly reduced in a low frequency range up to the

limiting frequency $f_{g1}$. For high signal frequencies, the feedback loop is closed by means of the capacitors 15a, 15b, so that the feedback is stable.

Figure 6 shows the differential output impedance of the driver circuit 1 as a function of the frequency. In this case, Z9a, Z9b are the output impedance values of the protection impedances 9a, 9b and A is the open signal gain of the operational amplifiers 3a, 3b. Up to a first limiting frequency $f_{g1}$, the output impedance of the driver circuit according to the invention is reduced by the gain factor A.

The limiting frequency $f_{g1}$ is determined by the capacitance of the capacitor 15 and by the resistance of the resistor 16 of the feedback circuit 14.

$$f_{g1} = \frac{1}{2\pi R_{16} \cdot C_{15}} \tag{4}$$

As already specified in equation (3), the following holds true for the longitudinal conversion loss LCL:

$$\mathrm{LCL} \cong 20 \cdot \log\left|\frac{R_L + Z_{out}}{\Delta Z}\right| \tag{3}$$

The frequency-dependent signal feedback by the signal feedback circuit 14 greatly reduces the output impedance $Z_{out}$ and the impedance difference $\Delta Z$ within the voice band, up to the limiting frequency $f_{g1}$. As emerges from equation (3), this leads to a great increase in the longitudinal conversion loss LCL. Typical values are 80 ohms for the output impedance and 0.5 ohm for the impedance difference. The longitudinal conversion loss

LCL is 57.6 dB for this case. If the output impedance $Z_{out}$ and the impedance difference $\Delta Z$ are reduced by the factor A = 100 by the feedback circuit 14 according to the invention, a value of 95.6 dB results for the longitudinal conversion loss LCL.

Consequently, in the case of the driver circuit according to the invention, the longitudinal conversion loss LCL can be considerably increased even with the use of inexpensive and inaccurate components on account of frequency-dependent feedback.

List of reference symbols

| | |
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| 1 | Driver circuit |
| 2 | Signal input |
| 3 | Amplifier circuit |
| 4 | Input |
| 5 | Input |
| 6 | Line |
| 7 | Output |
| 8 | Line |
| 9 | Protection impedance |
| 10 | Line |
| 11 | Signal line connection |
| 12 | Measuring resistor |
| 13 | Measurement signal source |
| 14 | Signal feedback circuit |
| 15 | Capacitor |
| 16 | Resistor |
| 17 | Input |
| 18 | Input |
| 19 | Output |
| 20 | Feedback line |